Recent reduction in NO_x emissions over China: synthesis of satellite observations and emission inventories

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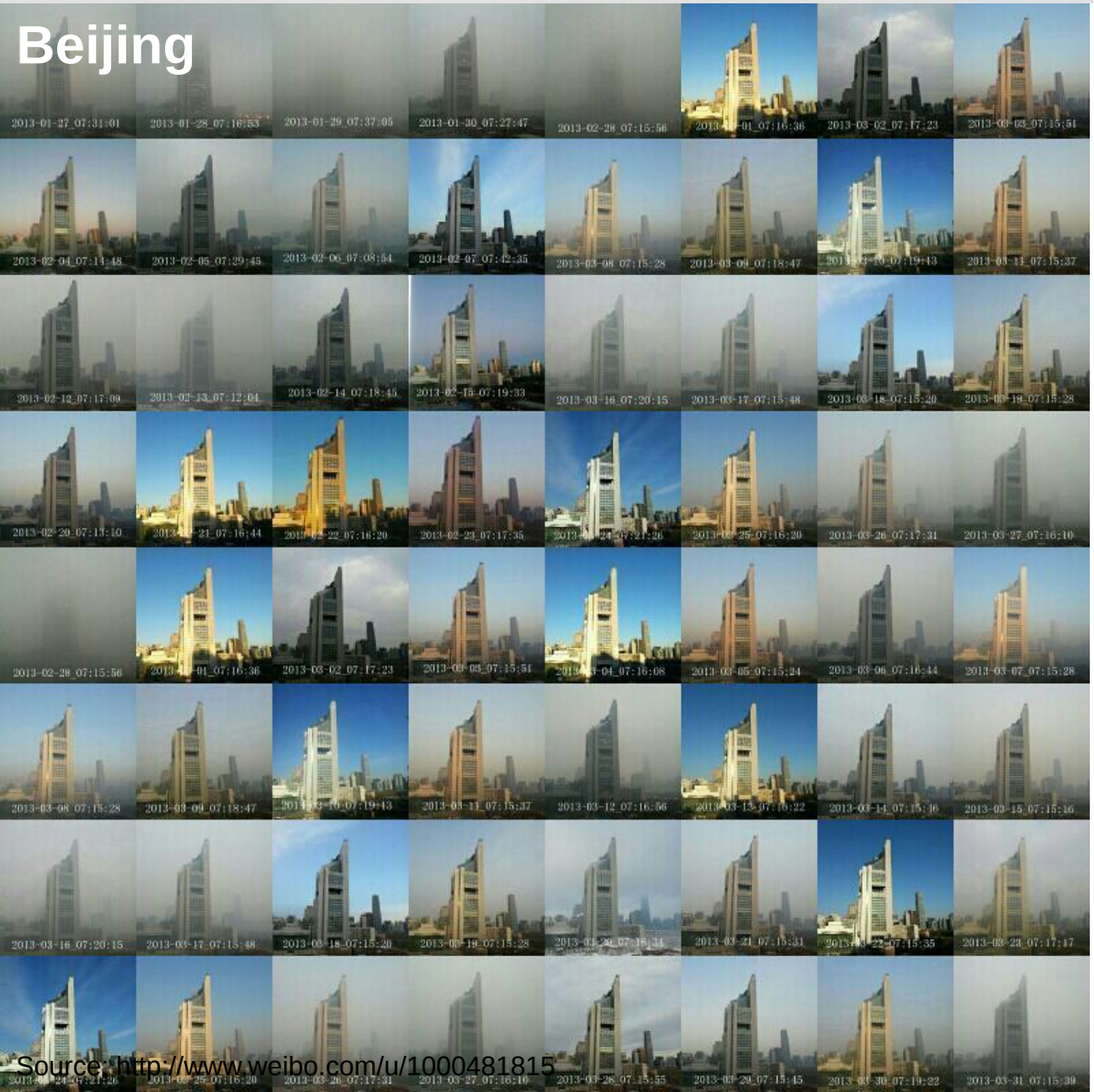
Motivation of cleaning China's air



Source: http://www.weibo.com/u/1000481815

Air Quality APP

Action & Concern

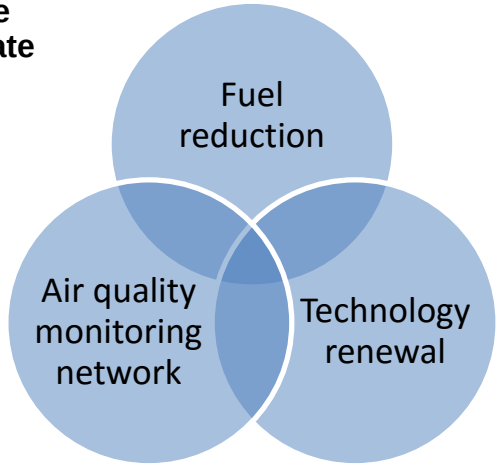
regulation

2012 ← First national environmental standard for fine particles (The Ambient Air Quality Standards, GB3095-2012) issued by state council

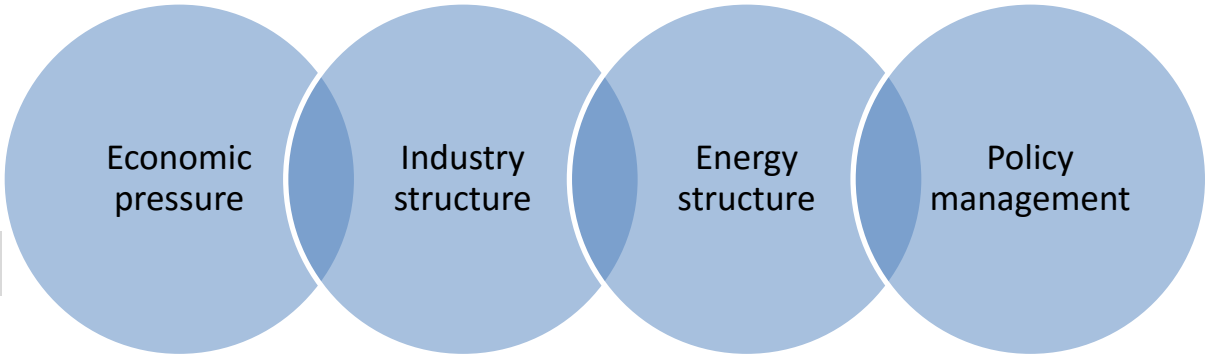
2013 ← Air pollution prevention and control action plan issued by state council

2014 ← New environmental protection law issued by state council

2015 ← Revised law on the prevention and control of atmospheric pollution



challenge



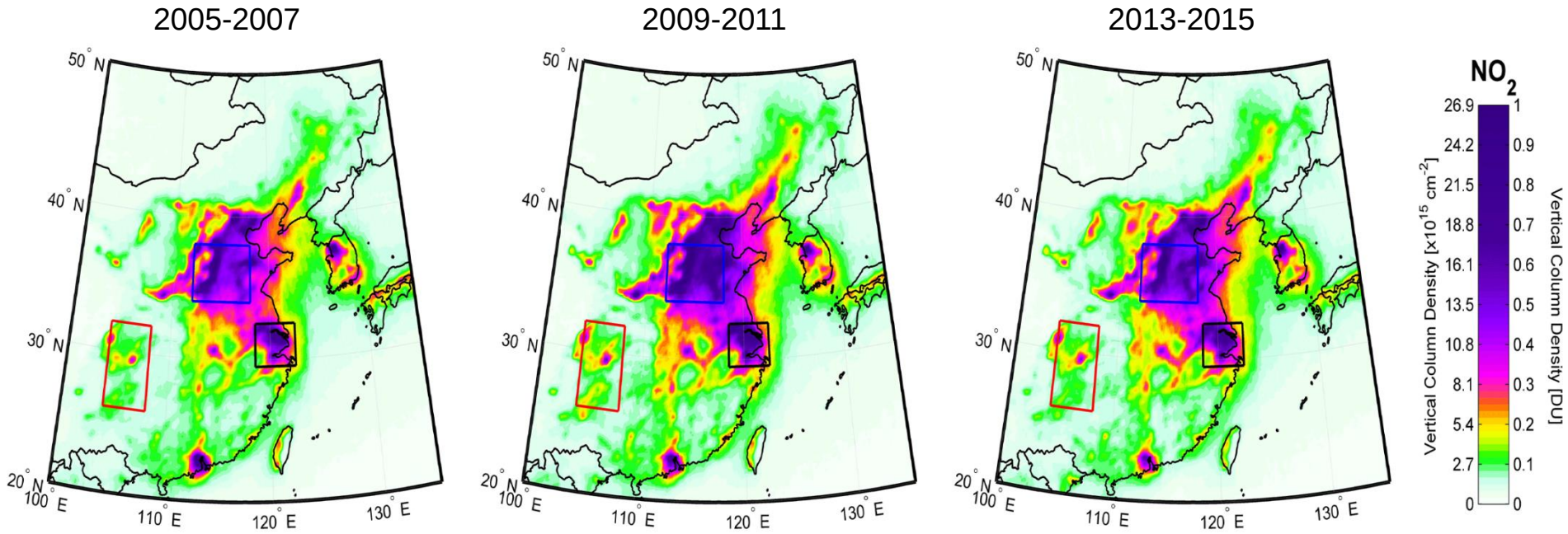
COMMENT

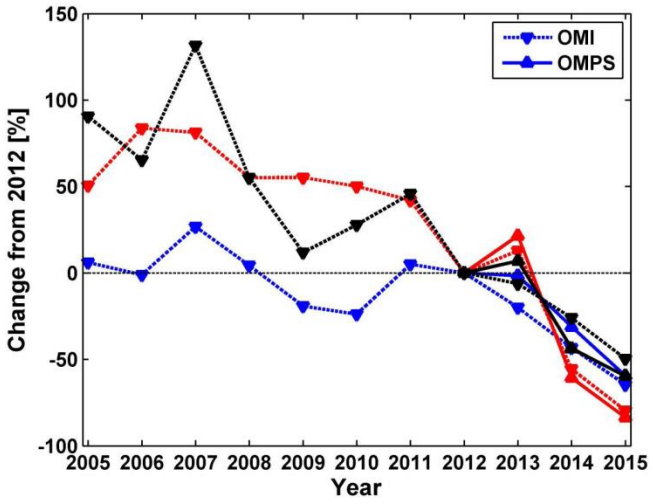
Cleaning China's air

To reduce airborne soot, organics and sulphates, tailored strategies for each must be established and coal use limited, say Qiang Zhang, Kebin He and Hong Huo.

Zhang Q, He K, Huo H. Policy: Cleaning China's air. *Nature* **484**, 161–162 (2012).

Previous observed decline in OMI NO_2 columns

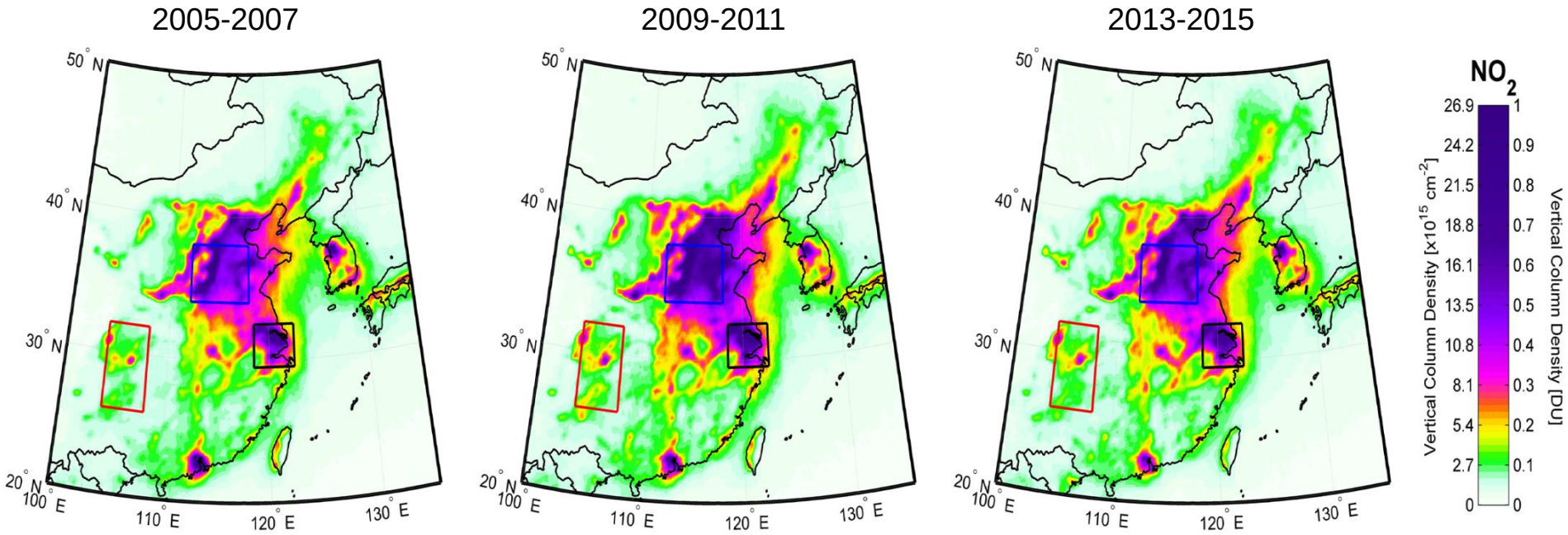




- NO_2 over the North China Plain peaked in 2011 after dramatic 50% increase since 2009 and decreased slightly in 2012 and 2013
- A dramatic 40% drop in NO_2 was widely observed in 2014–2015

Krotkov NA*, et al.* Aura OMI observations of regional SO_2 and NO_2 pollution changes from 2005 to 2015. *Atmos Chem Phys* **16**, 4605–4629 (2016).

Research questions



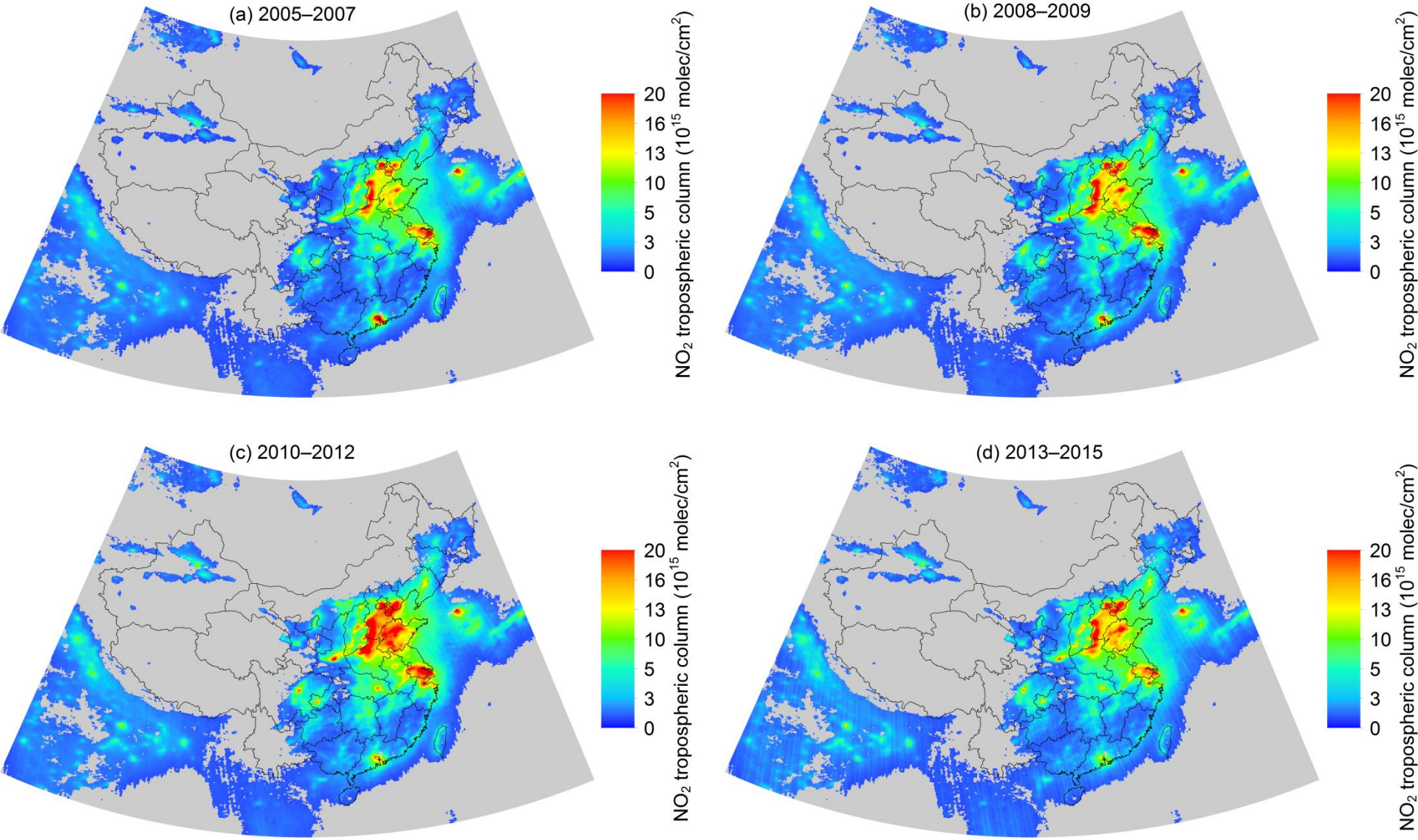
- **Where**: In which region did the NO_2 decline happen?
- **When**: Is there any regional diversity in the timeline of the NO_2 decline?

➡ Analysis at a regional level

- **Why**: Can we give in depth interpretations of the causes of the NO_2 changes?

➡ Intercomparison with independent information

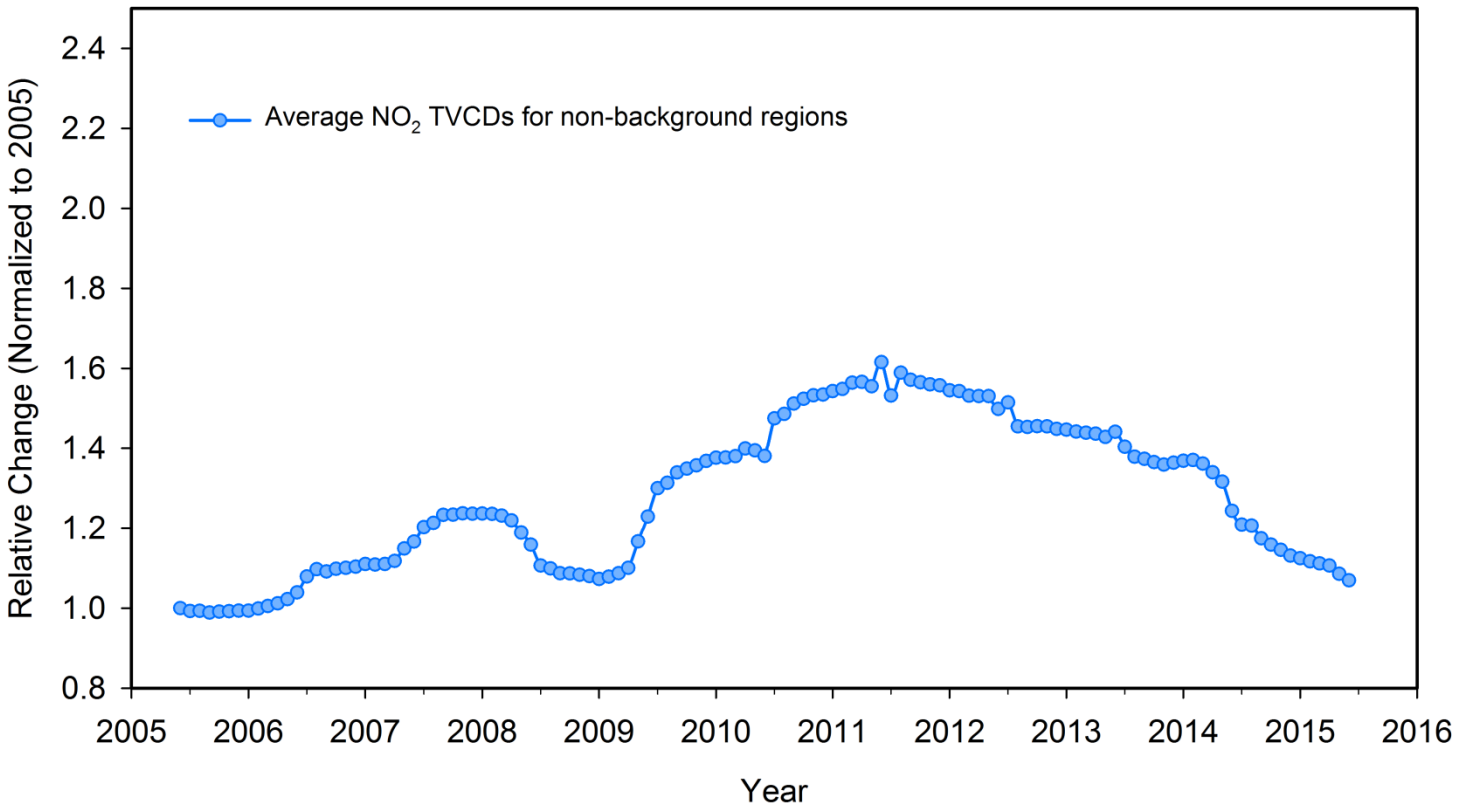
OMI NO_2 observations



Background regions: average annual NO_2 column densities less than 1×10^{15} molec/cm^2 or with average NO_2 column densities for summer exceeding those for winter

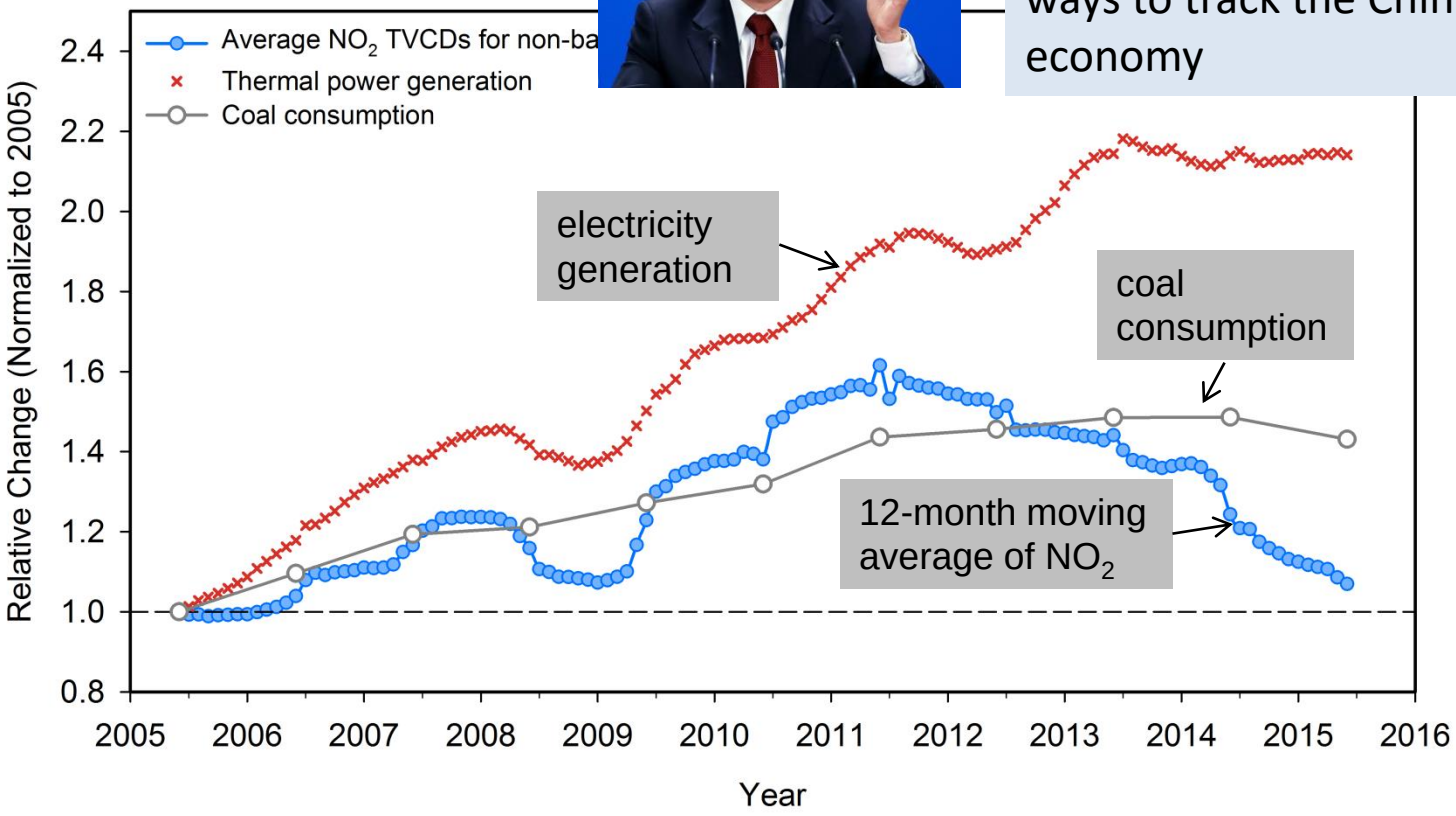
OMI NO_2 observations

12-month moving average of NO_2



OMI NO_2 observations

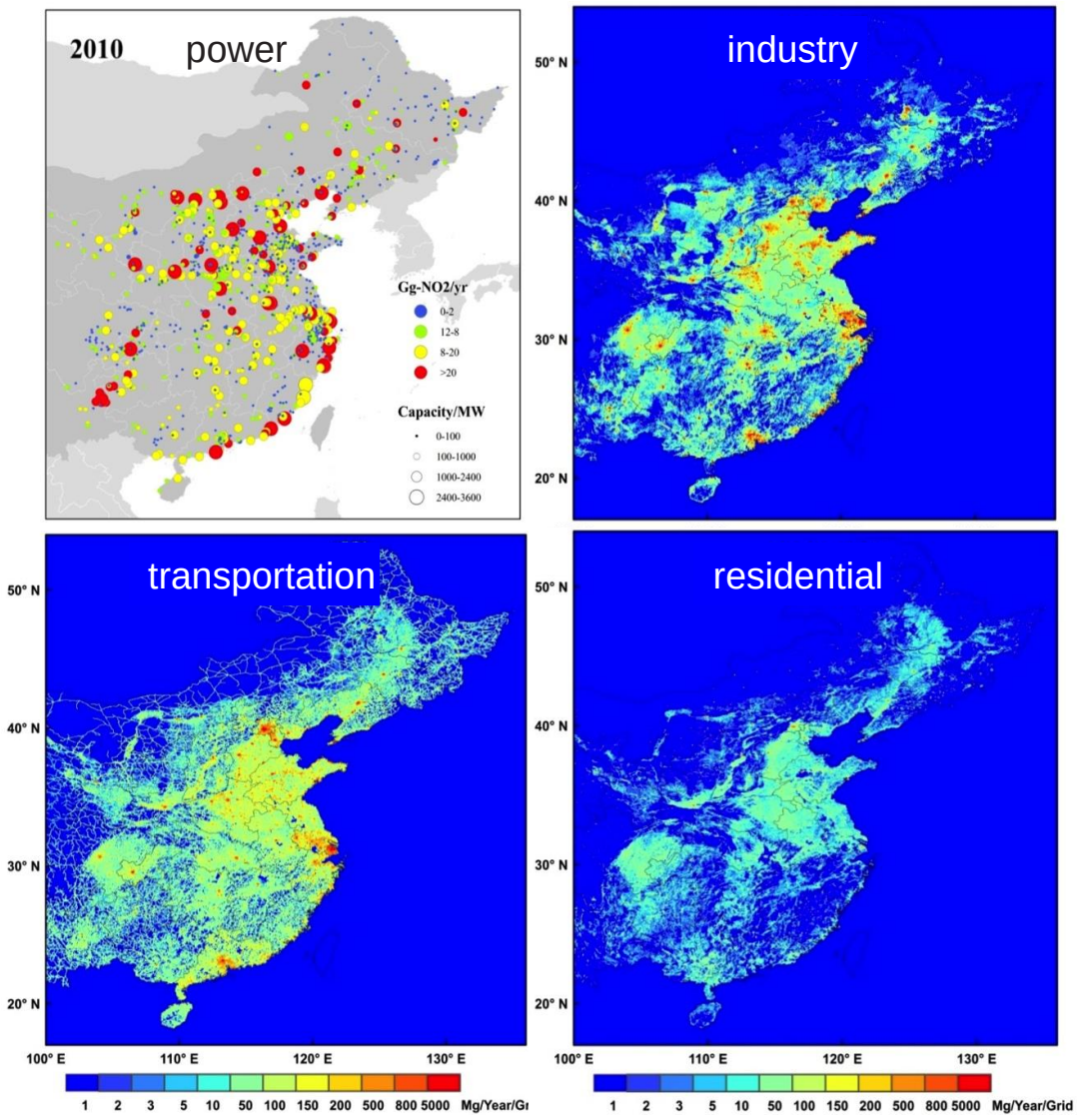
the Li Keqiang index: most important alternative ways to track the China's economy

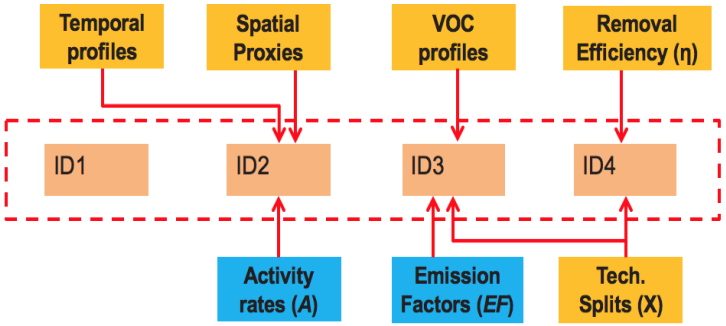


Electricity & coal consumption could not explain the simultaneous decline in OMI NO_2 column densities but suggests the effectiveness of emission control measures.

Bottom-up emission inventory

Emission by sector





ID1: sectors
ID2: fuel/product
ID3: technology
ID4: emission control

$$Emissions = A \times X \times EF \times (1-\eta)$$

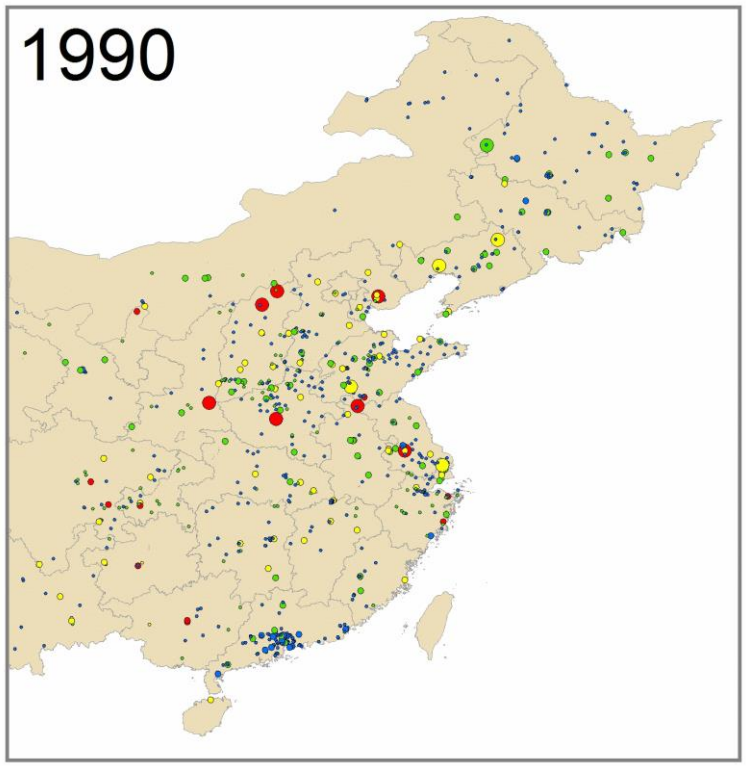
Uncertain:
emission factor
Robust:
activity rates (fuel consumptions);
Technology splits

robust emission trend

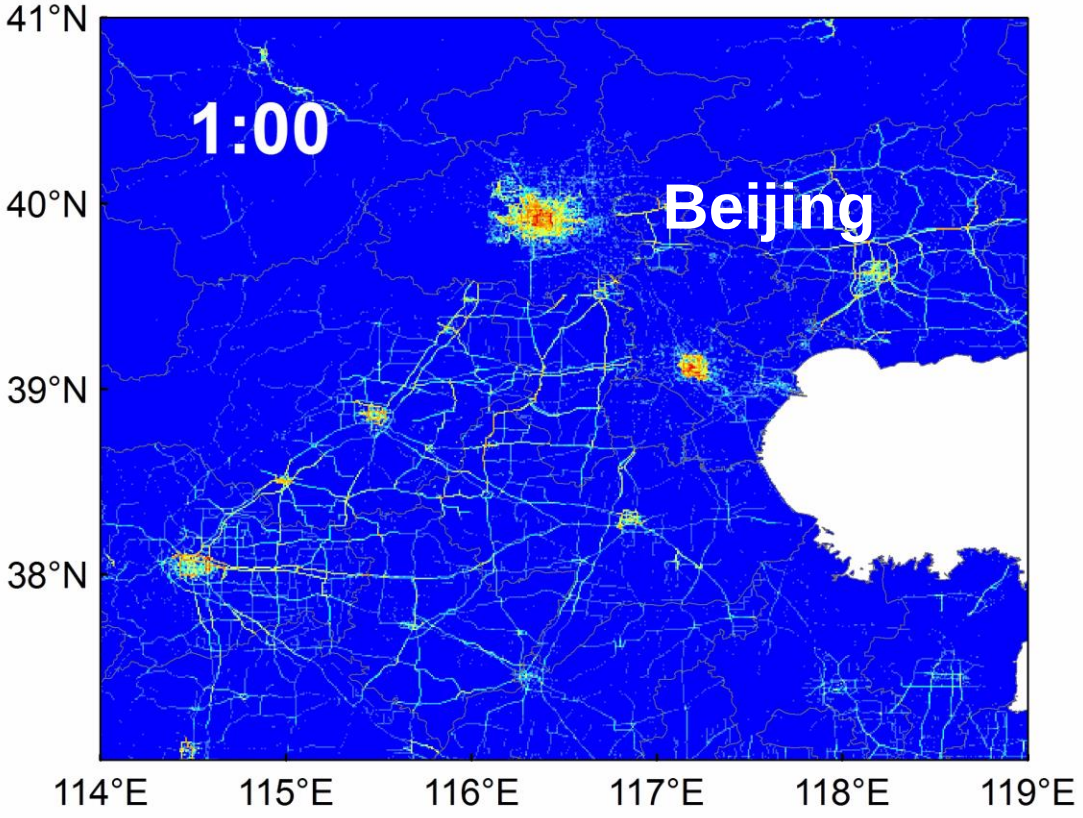
Bottom-up emission inventory

Multi-resolution Emission Inventory for China (MEIC: http://www.meicmodel.org) compiled by Tsinghua University

Power plant



On-road vehicle

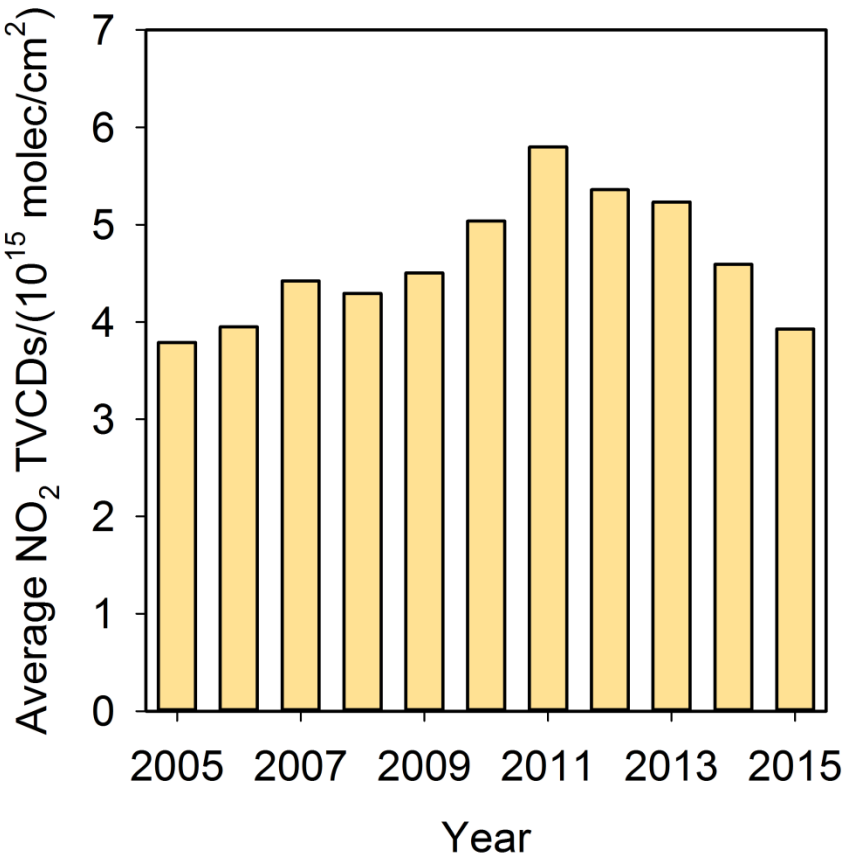


Liu F*, et al.* High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010. *Atmos Chem Phys* **15**, 13299–13317 (2015).

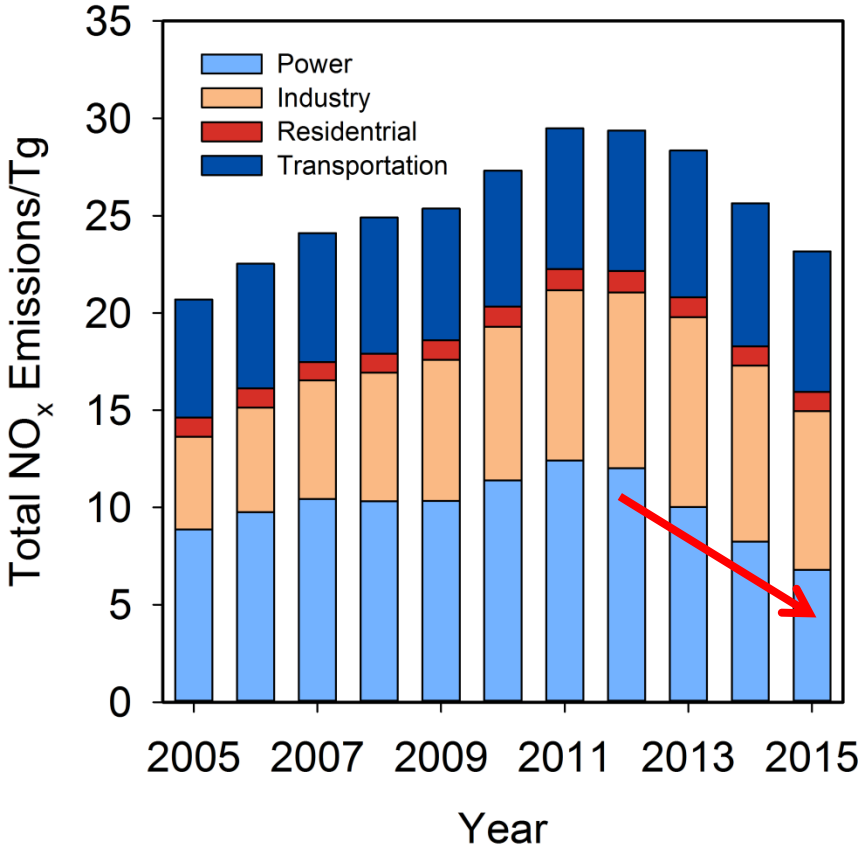
Zheng B*, et al.* High-resolution mapping of vehicle emissions in China in 2008. *Atmos Chem Phys* **14**, 9787–9805 (2014).

Agreement between top-down and bottom-up

OMI NO_2 columns



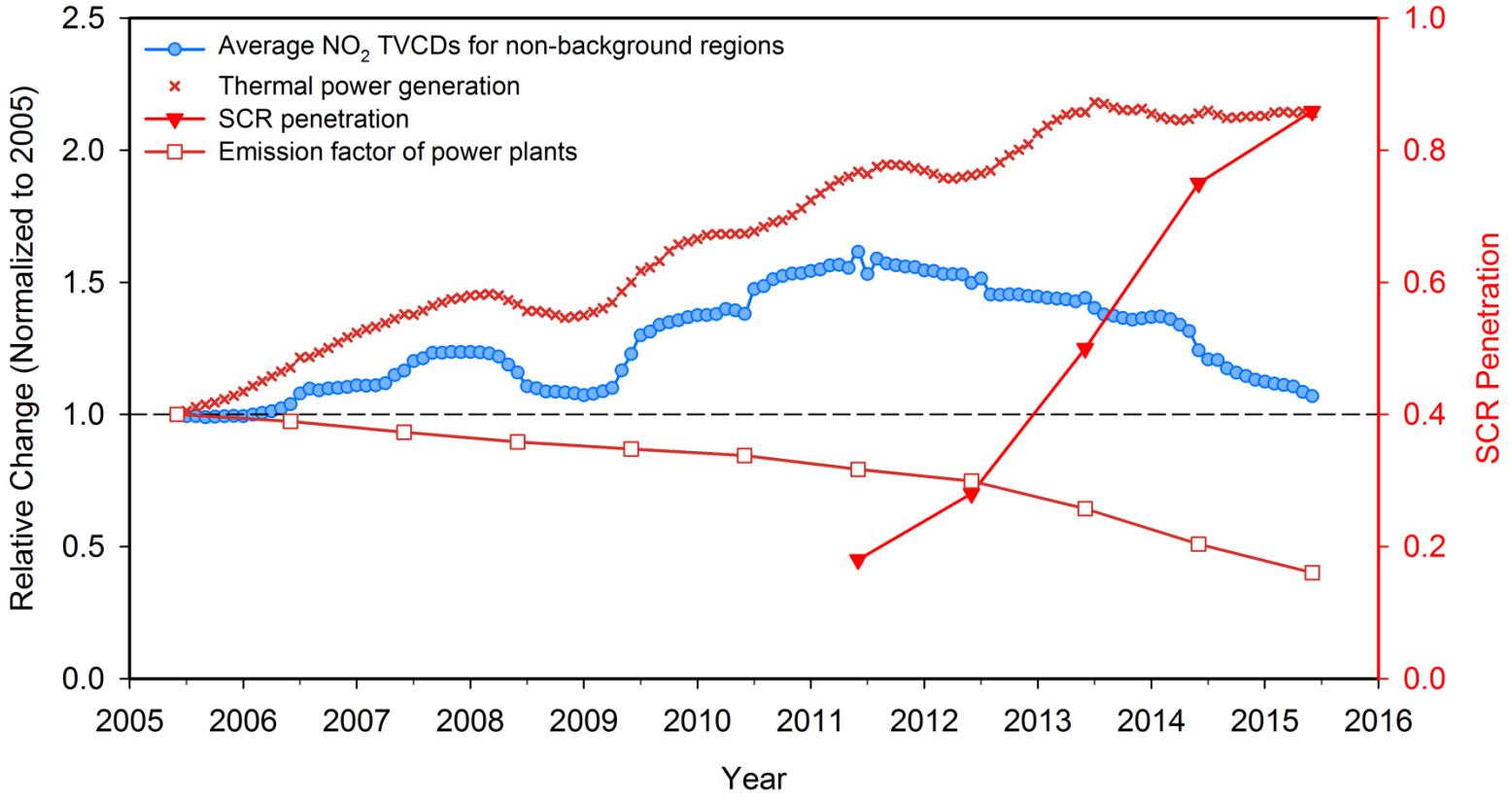
MEIC NO_X emissions



Emission reduction from power plant sector is significant

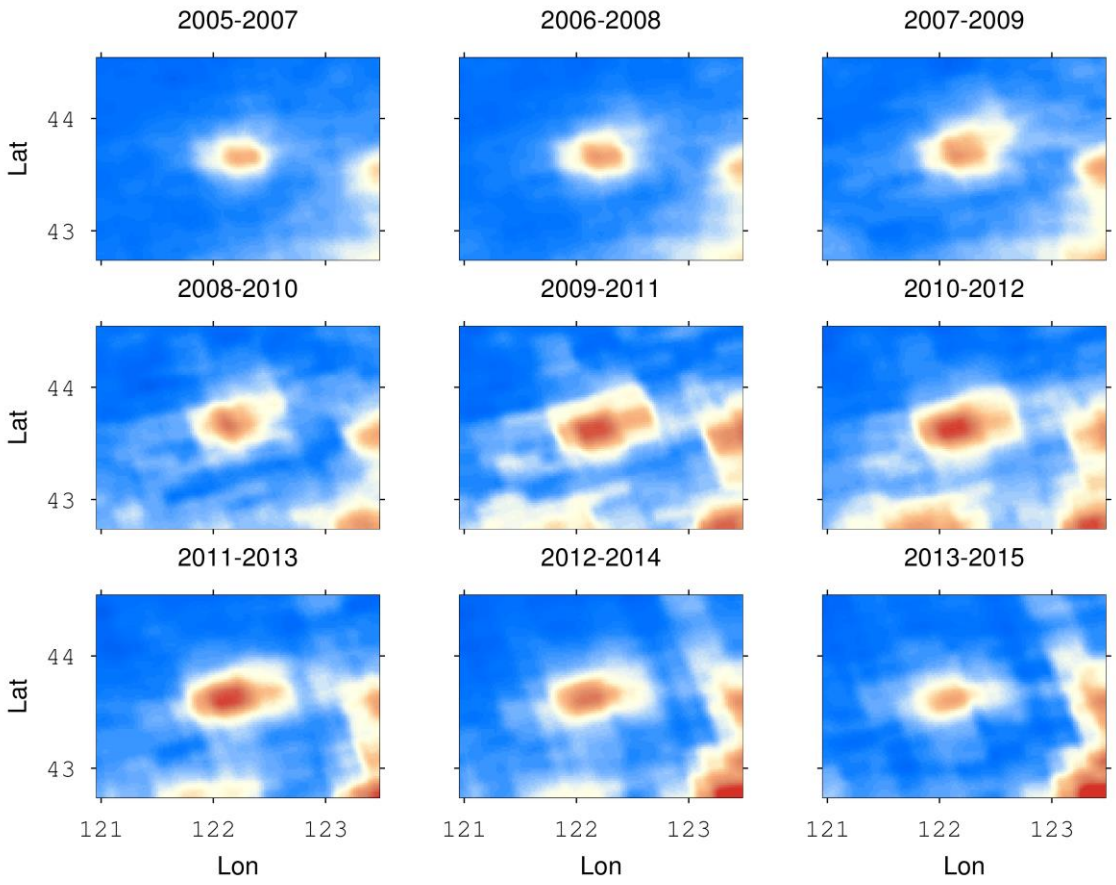
Liu F, *et al. Recent reduction in NOx emissions over China: synthesis of satellite observations and emission inventories*, ERL, in review.

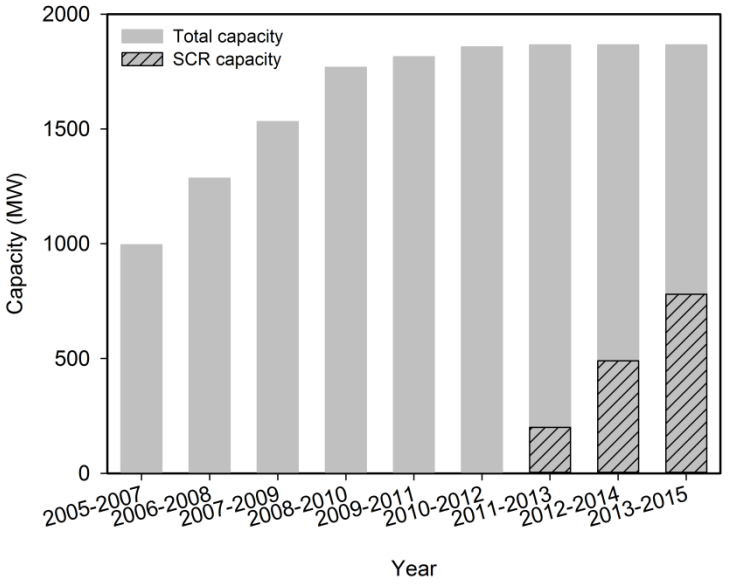
Installation of denitration devices for power plants

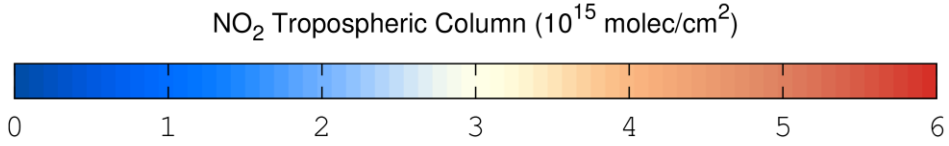


- New emission standard for power plants in 2011
- The market share of denitration devices increased from 18% to 86%
- The average NO_x emission factors of coal-fired power plants decreased from 6.2 g/kg to 2.6 g/kg from 2011–2015

Power plant located in Tongliao, Inner Mongolia



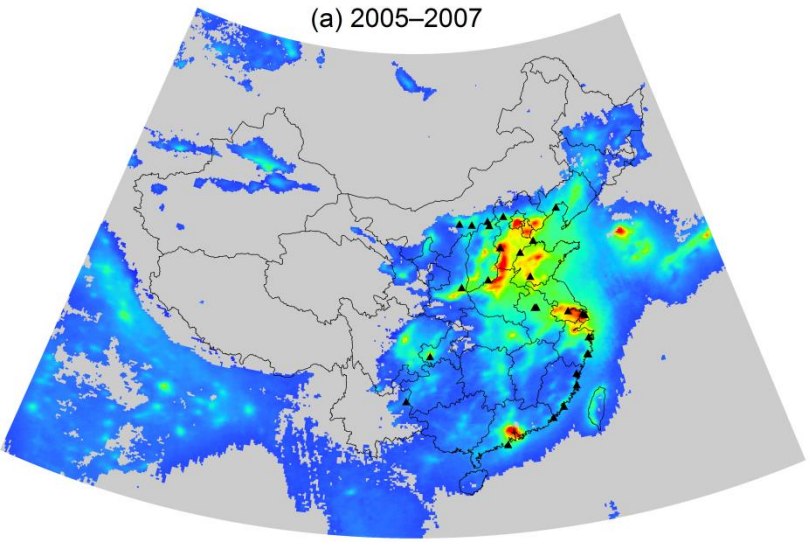




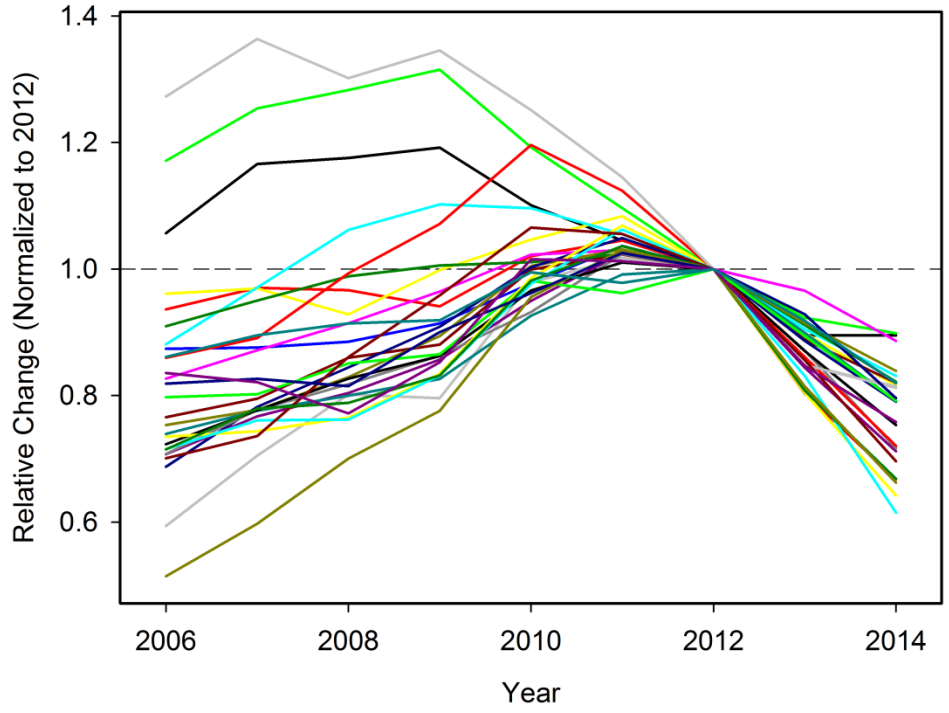
- total capacity: stable
- denitration devices: Increase
- NO_2 columns decrease

Decline in NO_2 columns around power plants

- Only power plants with a capacity over 2000 MW were selected
- 27 large power plants in total
- Overall unit capacity for the selected power plants reached 11% of the total national capacity
- Significant decline after year 2012

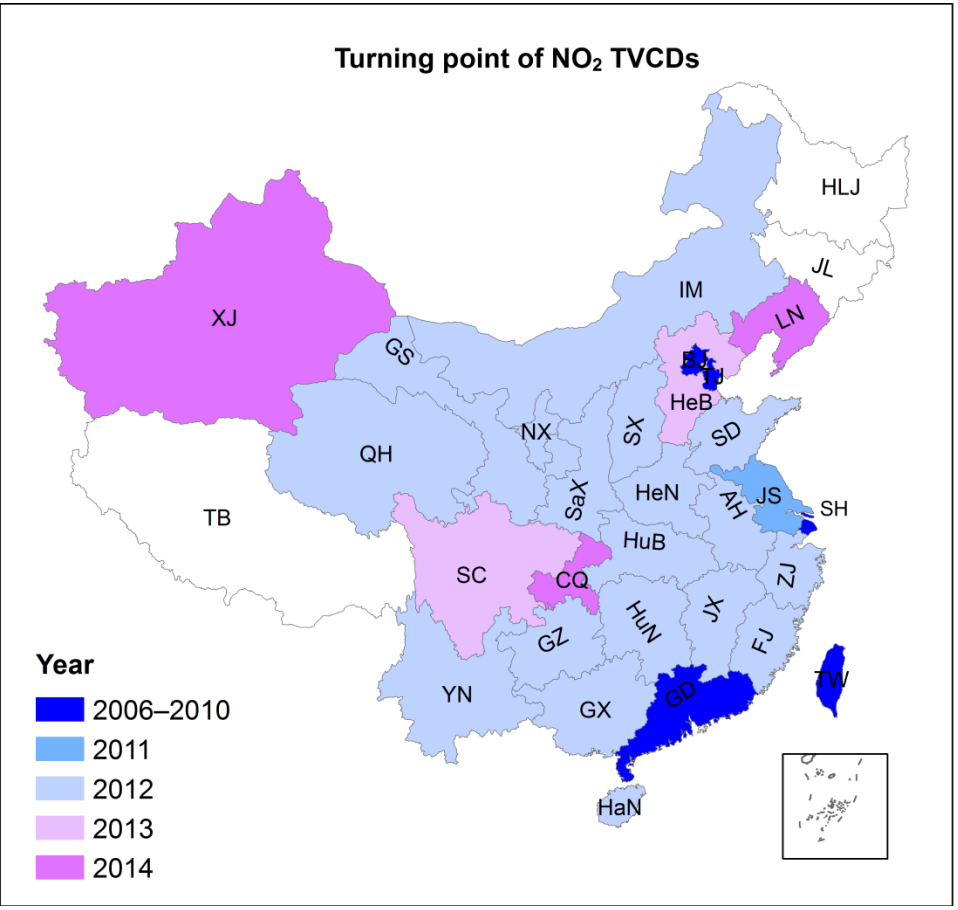


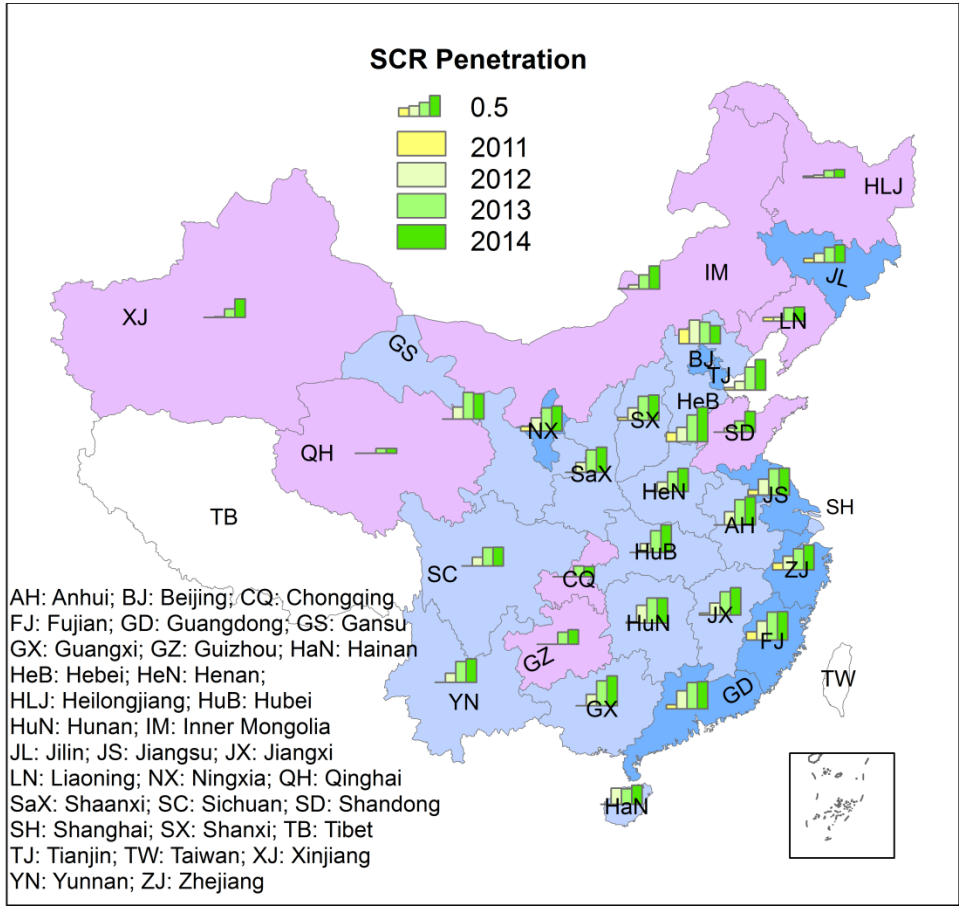
Average NO_2 columns



NO_2 decline VS denitration process

- The deployment procedure of denitration devices for power plants is found to be in reasonable agreement with the peak year of NO_2
- A few urbanized regions (e.g., Beijing and Shanghai) reached their NO_2 peak ahead of the deployment of denitration devices for power plants





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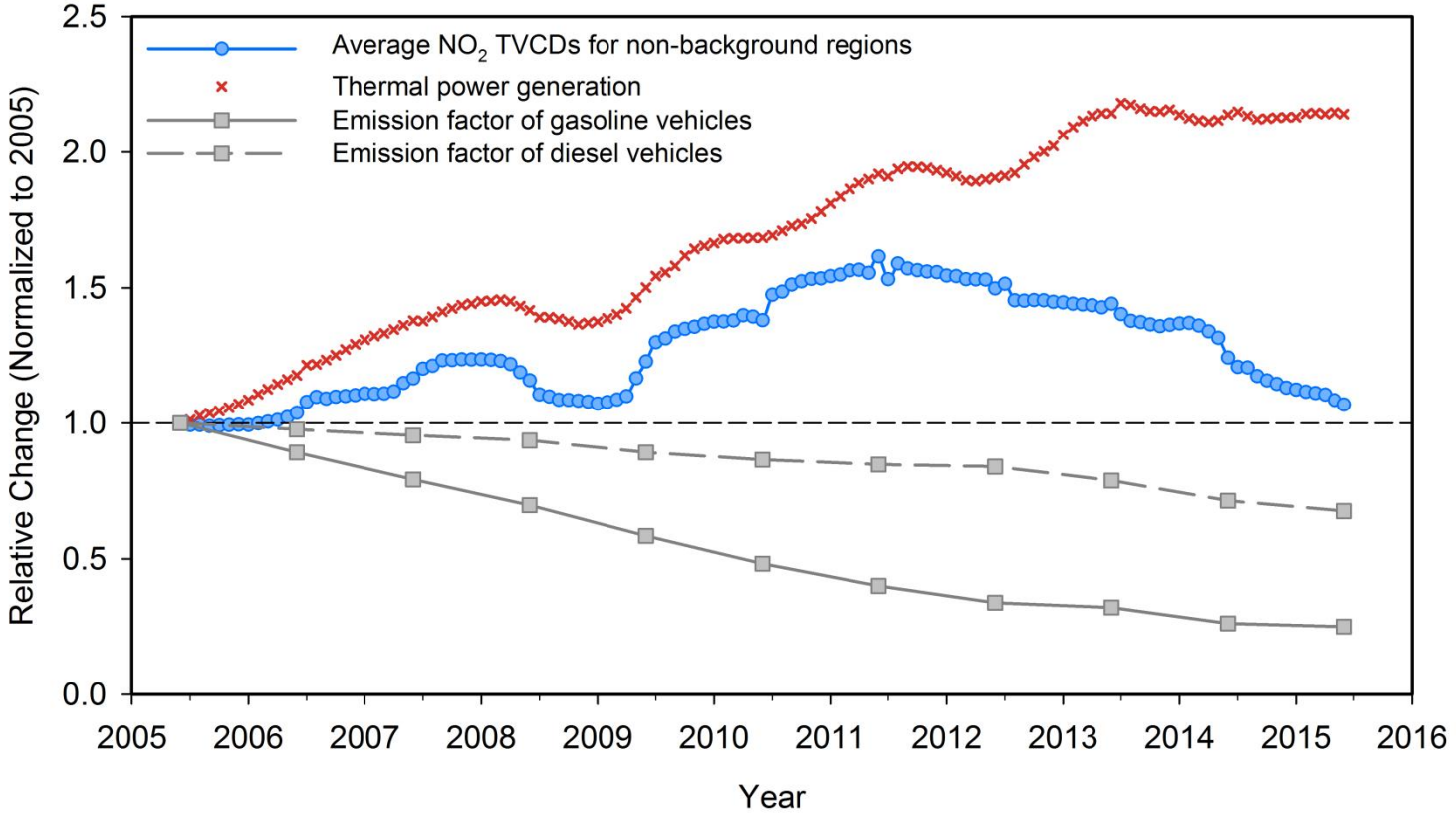
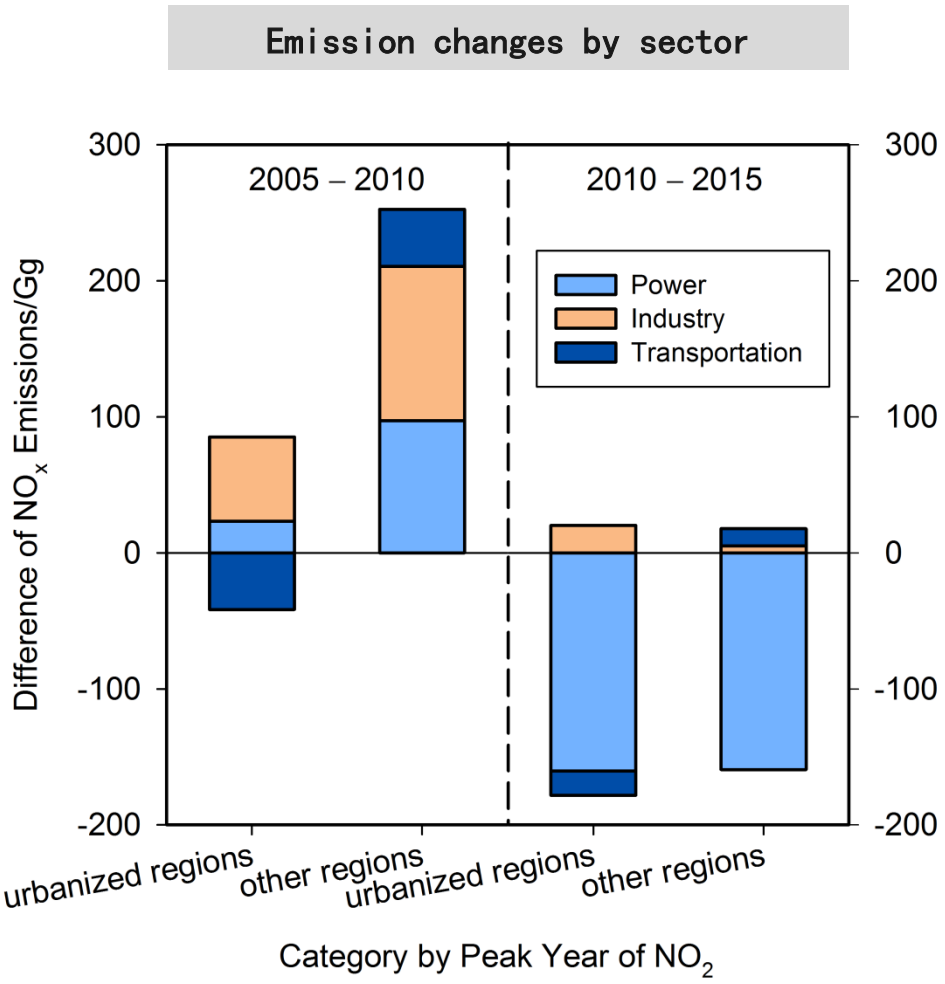
Emission control in transportation sector

Gasoline and diesel vehicles showed a continual decline in average NO_x emission factors, decreasing by respectively 75% and 32% during 2005–2015



Contribution from vehicles



urbanized regions:
Provinces which reached a NO_2 maximum prior to 2010
Including Beijing, Tianjin, Shanghai & Guangdong

Urbanized regions implemented strict regulations for vehicle emissions years before the SCR installations

- New emission standard for vehicles ahead of the national schedule
- Slow down of the speed of vehicle population expansion
- local policies for controlling vehicle populations
- Vehicle retirement programs to scrap aged vehicles
- Expanding underground road networks
- Promotion of alternative fuel technologies

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Take home messages

- The temporal variation of mean OMI NO_2 column densities of China is in good agreement with the bottom-up emission inventory.

- The peak year of NO_2 is closely related to the year of the installations of denitration devices, which suggested that the observed reduction in NO_2 was primarily the result of installing denitration devices for power plants.

- The peak year of NO_2 showed a strong diversity over the regions. The NO_2 columns of urbanized regions like Beijing, Shanghai and Guangdong peaked prior to 2010, which was expected as a result of control of vehicle emissions.